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human adaptation to strange environments

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The space age has prompted life scientists to find new ways of answering old questions, such as: Can man survive and perform effectively in strange and exotic environments? What are the thresholds and rates of adaptability to such environments?

Optimistic forecasts have been made on man's ability to perform effectively in outer space for indefinitely long periods. These forecasts have been based upon general human adaptability to adverse and new circumstances and conditions on, below, and above the earth's surface. Some of the conditions known to be characteristic of outer space, such as zero gravity and rapid temperature changes, have been simulated in experiments for short periods of time. To date, even in space flights, astronauts have not as yet experienced prolonged periods of free movement under zero gravity.

A team of physiological psychologists under AFOSR contract are inclined to be less optimistic in their forecasts of easy human adaptability to new space environments. Dr. Sanford Freedman of Tufts University, and Dr. Richard Held, now Professor of Experimental Psychology at MIT, have come to this cautious judgment during their program of experimental research studies on human performance under conditions of reduced and abnormal sensory input related to restriction of bodily movement.

In a recent report,[1] they agree with the optimistic view that human subjects show a remarkable ability to adapt to conditions of sensory rearrangement and distortion. They have demonstrated this by experimentally induced distortions through such devices as: (1) increasing the optical distance between hand and eye; (2) rotating the visual field with right-angled prisms; and (3) displacing the ears, in effect, to new positions around the head by means of electronic pseudophones. However, they have found that such adaptation has been achieved by the experimental subject only when he was allowed free movement either of his

whole body, as in walking, or of an appropriate limb. If he is either restricted in his movements, or if he is passively moved to provide him with variation in sensory stimulation equivalent to that received with free movement, no comparable adaptation is obtained.

These experiments indicate that a motor-sensory feedback loop provides information which permits the human sensorimotor system to reset its response patterns when it is confronted with a new environment. Under normal conditions of life, the visible world is crowded with many objects, of which a great proportion are stationary. Bodily movements are, for the most part, the results of muscular exertion against the counterforces of objects and gravity. Muscular exertion then produces corresponding bodily movement. Taken together, the physical conditions produce the information required for correlating nerve signals which control movement.

When, however, the body or its parts are prevented from making contact with external objects in a normal and consistent manner, muscular contraction may be unrelated to certain aspects of bodily movement. The astronaut, in free flight during a ballistic trajectory (when he is not strapped down), is free to push on objects; but the result may be a radical change from the high correlation between motor-output signals and their sensory consequences experienced on earth.

The experiments in vision and hearing conducted by Freedman and Held have supported the view that, when there is a prolonged exposure to conditions which do not permit a correlated feedback, the accuracy of performance is degraded.

Their findings do more than reiterate the obvious fact that an organism can be adapted only to the regularities of the world. Less obvious is the conclusion that stimulus changes which accompany movement of the human organism are an important source of order in adaptation. This order is dependent upon the relative constancy of several physical factors, one of which is gravitation. In the absence of one or another of these factors, coordinations which depend upon their regularizing influence may, in time, be lost.

This appears to have significant implications for human performance in space. To the extent that an astronaut is exposed to "uncorrelated feedback," degraded performance can be expected on relevant tasks. Such losses may be prevented by restricting bodily movement during exposures that produce the physical changes responsible for disrupting the necessary correlation.

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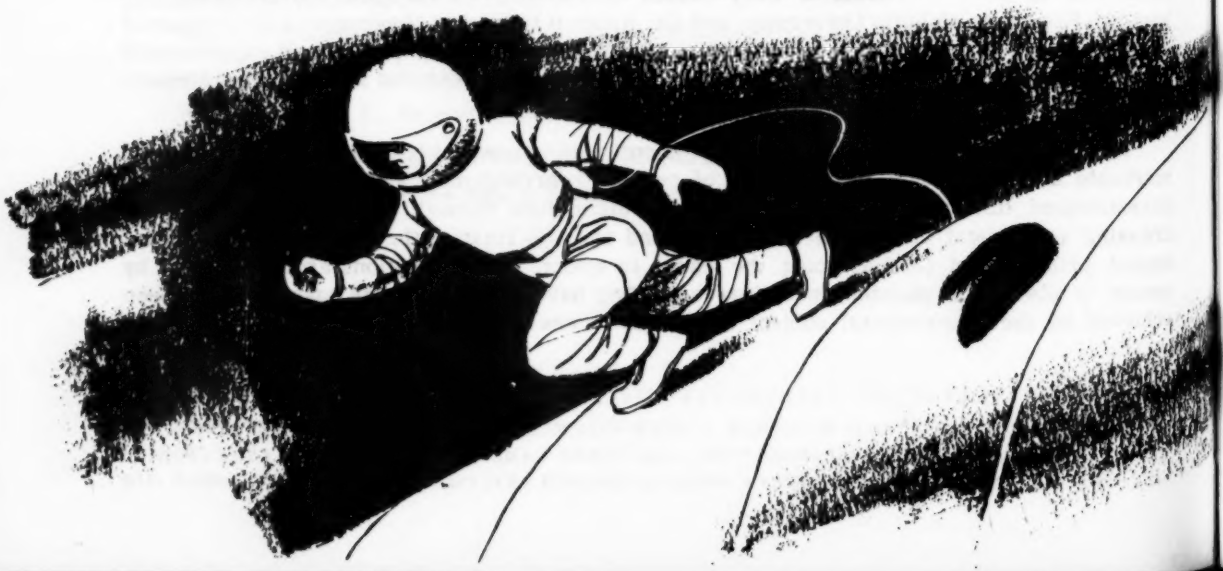
[1] "Plasticity in Human Sensorimotor Control - Studies of Disordered Motor-Sensory Feedback Raise Questions About Man's Coordination in Outer Space," to be published in SCIENCE.



BY THE NUMBERS

MAJOR B. R. AGINS, *Applied Mathematics Division*, AFOSR

The modern digital computer has made possible solutions of relatively complicated ordinary differential equations by numerical integration. Certain standard procedures are available based on a Runge-Kutta formula or multistep formulas of Milne or Adams. Automatic estimation of single-step error can be provided as long as the error is due primarily to truncation.

Recently, a more general approach to numerical integration has been initiated. The objectives are to develop a mathematical theory of methods for numerical integration and to make the design of optimum methods an automatic procedure. One of the leaders in the area of the general approach is Professor T. E. Hull of the University of British Columbia. Professor Hull has treated multistep techniques from the point of view of designing optimum methods and their existence, stability and convergence.

Working under a grant from the Applied Mathematics Division of AFOSR, Professor Hull has completed a study * on how the relationship between accuracy and cost depends on the choice of predictor-corrector formulas and on the iteration rules.

The initial value problem considered was $X' = f(t,x)$, $X(t_0)=X_0$

where $f(t,x)$ is fairly complicated (such as nonlinear functions of x and t and transcendental in t). The predictor-corrector procedure consists of using a predictor formula to obtain an approximate value of x at a given point and $f(x,t)$ is evaluated to obtain an approximation to X' at the point. The corrector formula is applied to correct the value of X and the evaluation-correction is iterated until the desired degree of accuracy is attained. The procedure is repeated at each point.

The measure of the cost was the total number of evaluations of $f(X,t)$. The relationship between accuracy and cost was examined for dependence on the step number and the number of iterations for general-purpose procedures. The results indicated that the formulas of the Adams type are most suitable, that at each step there should be two evaluations of the function and two applications of the corrector, and that the step size should be chosen according to accuracy and stability criteria which are dependent upon the differential equation.

* Hull, T. E. and Creemer, A. L., "The Efficiency of Predictor-Corrector Procedures," JOURNAL of ACM, Vol. 10, No. 3, July 1963

an equation for the coefficient of viscosity at LOW TEMPERATURES

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In aerodynamic research there are certain similarity parameters which must be reproduced in order to insure that proper flight conditions are simulated in a wind tunnel. Some of these parameters are the Reynolds number, Prandtl number, and the mean free path. Each of these is a function of the viscosity. For this reason the proper form of the equation for the coefficient of viscosity is important. In transonic and supersonic wind tunnels, the practice has been to use Sutherland's equation for the viscosity. Under these conditions, the free-stream temperature is relatively high; therefore, the use of this equation is justified. The form of Sutherland's equation is obtained from the kinetic theory of gases, while the constants are determined by experimental techniques. It is usually written as

$$\mu = \mu_r \left(\frac{T}{T_r}\right)^{3/2} \left(\frac{T_r + S}{T + S}\right) \qquad \text{for } 198.6^\circ \text{ R} \leqq T \leqq 3500^\circ \text{ R} \qquad (1)$$

where the constants are $\mu_r = 3.584 \times 10^{-7}$ slugs/ft sec

$$T_r = 492^\circ \text{ R}$$

$$S = 198.6^\circ \text{ R}$$

and μ is the coefficient of viscosity and T is the free-stream temperature. In hypersonic wind tunnels the free-stream temperature, which varies from 50° R to approximately 200° R, is much lower than in transonic and supersonic facilities. For these temperatures, Sutherland's equation is questionable.

Figure 1 presents a plot of viscosity versus the temperature based on Sutherland's equation. Superimposed on this are the Bromley-Wilke data for air taken from Reference 1. Although it is not shown in Figure 1, the Bromley-Wilke data agree with Sutherland's equation at free-stream temperatures above 198.6° R. This figure does show that the use of Sutherland's equation below a temperature of approximately 200° R can result in an excessive error. Therefore, it is necessary to obtain another expression for the viscosity for the lower temperature range. The new equation should have the following features:

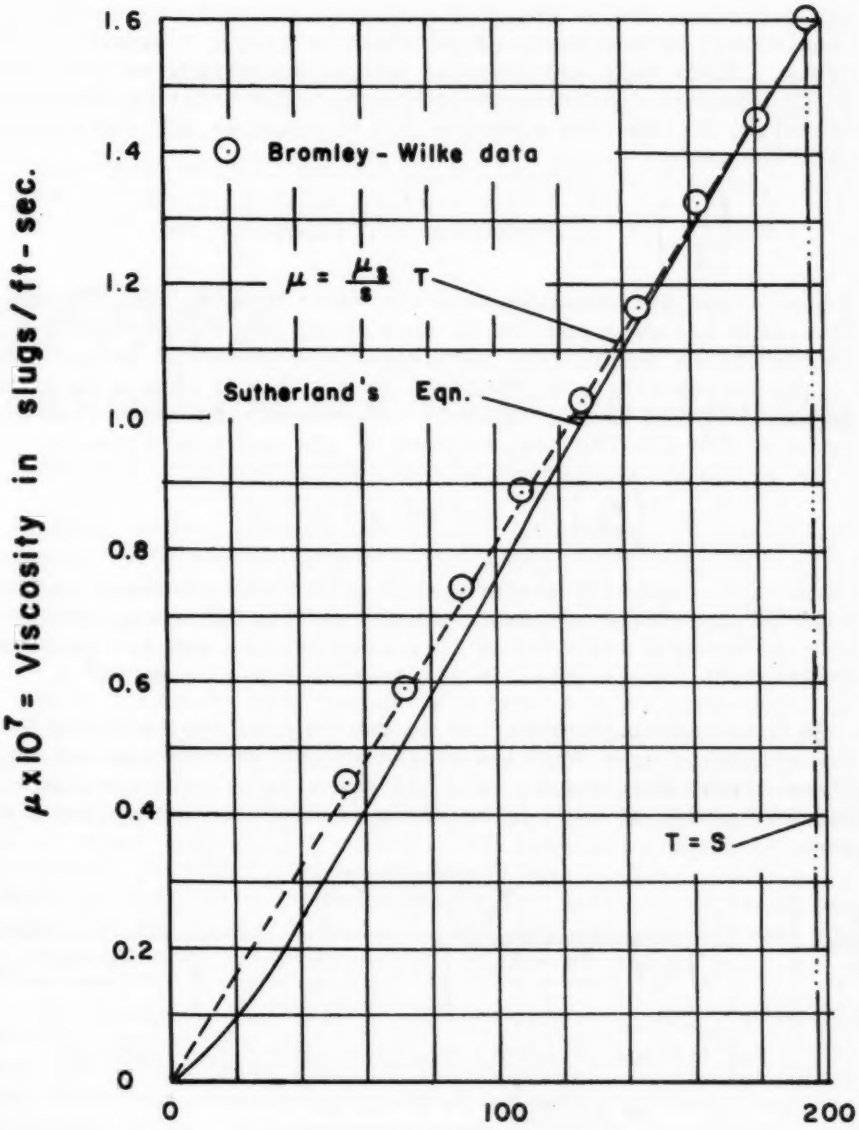
a. It should be a reasonably good "fit" of the Bromley-Wilke data.

b. Its mathematical form should be simple so calculations will not become cumbersome.

Fig. 1 – Coefficient of Viscosity

Versus

Free-stream Temperature



c. It should match Sutherland's equation at 198.6° R so that the function remains mathematically continuous at the junction of the two curves. The Bromley-Wilke data on Figure 1 indicate that the linear form

$$\mu = AT \text{ for } 50^{\circ} R \leqq T \leqq S \tag{2}$$

would be a satisfactory approximation. The constant "A" is the slope of the curve and can be obtained either graphically or analytically. The analytical method was used in order to insure a greater degree of accuracy. Since only one constant had to be determined (the slope), only one boundary condition was required. The value of this constant was obtained by equating equation (1) to equation (2) for the condition T = S. The result is

$$A = \left(\frac{\mu_S}{S}\right) = 0.0080469 \times 10^{-7} \text{ slugs/ft. sec. } {}^{\circ}R \tag{3}$$

This same value was obtained when the first derivatives of both equations (1)and (2) were equated to each other for the condition T = S. These conditions insure that both equations yield the proper magnitude and slope of the viscosity function at T = S. It should be noted that μ_S is the value of the coefficient of viscosity obtained from Sutherland's equation at T = S. The desired form of the new expression is

$$\mu = \left(\frac{\mu_S}{S}\right) T \quad \text{for } 50^{\circ} R \leqq T \leqq S \tag{2a}$$

The above equation should not be used below a free-stream temperature of 50° R. There are two reasons for this recommendation: (1) no Bromley-Wilke data exist below this temperature; and (2) there is no guarantee that air is still in its gaseous state below 50° R.

In wind-tunnel programs, it is common practice to express the free-stream viscosity as a function of the stagnation temperature (T_o) and the free-stream Mach number (M). If one assumes that the vibrational degree of freedom of the air molecule is excited, Sutherland's equation becomes

$$\mu = \frac{\mu_r}{\sqrt{T_r}} \left(1 + \frac{S}{T_r}\right) \frac{\sqrt{T_o f(T_o, M)}}{\sqrt{1 + \frac{\gamma_p - 1}{2} M^2} \left[1 + \frac{S}{T_o f(T_o, M)} \left(1 + \frac{\gamma_p - 1}{2} M^2\right)\right]} \tag{1a}$$

and the new viscosity equation can be rewritten as

$$\mu = \left(\frac{\mu_S}{S}\right) \frac{T_o f(T_o, M)}{1 + \frac{\gamma_p - 1}{2} M^2} \tag{2b}$$

In these expressions the function $f(T_o, M)$ is the correction for the vibrational degree of freedom for the isentropic temperature ratio and can be found in reference 2.

It is important to notice that equation (2b) is not only more accurate than equation (1a) in the range $50 \leqq T \leqq S$, but its form is greatly simplified for calculation purposes.

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1. "Viscosity Behavior of Gases," by L. A. Bromley and C. R. Wilke, INDUSTRIAL AND ENGINEERING CHEMISTRY, Vol. 43, Nr. 7, pages 1641 to 1648, July 1951.
2. "Equations, Tables, and Charts for Compressible Flows," by Ames Research Staff, N.A.C.A. REPORT 1135.

AFCRL synthesizes new compound

DR. A. F. ARMINGTON, *Solid State Sciences Laboratory*, AFCRL

AFCRL scientists have synthesized a previously unreported compound, boron phosphide hexaiodide (BPI_6). The discovery of this compound could lead to the custom growth of single-crystal boron phosphide, a crystal having semiconducting properties of great interest.

This discovery grew out of research in III-V compounds, of which gallium arsenide is perhaps the best known example. III-V compounds may lead to new semiconductors that can operate at extremely high temperatures, lasers that can emit radiation over a wide range of wave lengths, and improved electroluminescent devices. Each of these compounds is synthesized from one element of Group III (boron, gallium, aluminum, indium, and thallium), and one element of Group V (nitrogen, phosphorus, arsenic, antimony, and bismuth) of the periodic table. AFCRL has investigated the growth and properties of III-V compounds for several years.

The immediate interest in the new compound, BPI_6, stems from the fact that it may lead to the preparation of the III-V compound, boron phosphide, in its desired stoichiometric form--that is, a boron-phosphide crystal having an equal number of boron and phosphorus atoms. The high-energy gap of boron phosphide suggests that it may have heat-resistant (and possibly radiation-resistant) properties found only in diamond semiconductors.

To realize these favorable properties of stoichiometric boron phosphide in useful devices, it must be prepared in single-crystal form. This has heretofore not been possible by conventional crystal-growth methods--pulling from a melt, epitaxial techniques, and the traveling solvent processes. AFCRL has investigated the preparation of these compounds by another technique--the decomposition of Group III and Group V iodides.

Three physical properties of the new compound make it attractive for use in the preparation of boron phosphide. The vapor pressure of the compound near room temperature is such that sublimation readily occurs. The compound decomposes at a lower temperature than that at which boron phosphide dissociates. Most important, boron phosphide hexaiodide contains an equal number of boron and phosphorus atoms. Consequently, there is a very high probability that the boron phosphide formed by the thermal decomposition will be stoichiometric.

X-ray analysis indicates that the boron phosphide hexaiodide does not decompose during sublimation and that cubic boron phosphide is formed by the decomposition of the new compound. Attempts will be made to grow boules, or crystals, of boron phosphide from the powdered thermal-decomposition product.

These promising results have led AFCRL to the synthesis of other III-V compounds. Synthesis of iodides of boron-antimony and boron-arsenic will be attempted. These compounds, it is hoped, will be used for the preparation of the III-V compounds boron antimonide and boron arsenide.

The research was conducted by Dr. A. F. Armington and Captain R. F. Mitchell.

photochemical *flashes*

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Directorate of Chemical Sciences
AFOSR

Most parents have at one time or another been confronted by an inquisitive child's desire to know "what makes plants green?" or "why is grass green?" In the way of a partial explanation, he might be told that carbon dioxide from the air combines with water in the presence of sunlight to form the chlorophyll which is a basic building block of all plants. A simple description such as this of the complex and still-not-completely understood photosynthetic process may serve to satisfy his curiosity, at least momentarily.

Many theories have been advanced for the mechanism of photosynthesis in an attempt to unravel the mysteries of this most vital process. In addition to this particular light-catalyzed reaction, light of varying wave lengths and intensities has been found to effect a wide range of chemical transformations. An understanding of degradative effects produced by ultraviolet light and other high-energy radiation upon materials, as well as the synthesis potentialities of light-induced polymerizations are other practical applications of the fundamental knowledge acquired through photochemical research.

Two major problems in understanding the detailed effects of light on photochemical systems have needed elucidation: (1) the fates of those molecules which absorb photons -- i.e. how many emit photons, how many dissociate, how many rearrange, how many merely lose energy to surroundings?; and (2) the reactions of the fragments of molecules which dissociate (these are usually atoms or radicals).

The second of these problems has attracted the attention of photochemists for several generations. Some photochemical reactions result from long-chain mechanisms. Others have short chains. In some rare instances, the fragments merely recombine to form the original absorbing molecule and no net reaction results.

With support by a grant from the Directorate of Chemical Sciences, AFOSR, Professor W. Albert Noyes, Jr. at the University of Rochester has been studying the relationship between energy absorption, energy transfer, and the natures of the electronic states involved in primary photochemical acts. The problems are complex and, in the absence of light emission which identifies the excited species, the conclusions are often difficult to substantiate.

One of the most important types of reaction apparently results from the transfer of hydrogen atoms from, e.g., one carbon atom to another by an intermediate ring structure. This process was first observed by Norrish and his co-workers at Cambridge University, England; but the detailed mechanism has been elucidated by the AFOSR-sponsored work at the University of Rochester. The ring structures which lead to reaction are almost certainly formed in excited molecules and do not exist in the normal state. The rings seem to involve mainly four and six atoms, although in very simple molecules three atom rings may participate.

Professor Noyes and his co-workers have shown that many ketones, including even ring ketones, dissociate or rearrange by transfer of hydrogen atoms either to give aldehydes or, in some cases, new ketones and unsaturated compounds. The use of isotopic tracers has shown clearly what happens in many cases.

Emission in the green range of the spectrum known to come from the triplet state of biacetyl may be used under certain circumstances

to identify the nature of excited species. A triplet-state molecule should, upon collision, excite the triplet state of biacetyl preferentially. Data are still meager, but evidence now exists in several cases to show that molecules initially formed in the singlet state almost always cross over to the triplet state unless they dissociate, fluoresce or are deactivated by collision. Thus, the reactions of excited molecules in triplet states become of paramount importance. Much of the work has been done in the direction of identifying these triplet-state reactions. It has been shown that there are steric factors which may prevent the excitation of biacetyl to green emission.

Photochemical research performed by Professor Noyes and others under AFOSR grants and contracts will benefit the Air Force by helping to solve the problems concerned with radiation effects and reaction in the upper atmosphere. It will also aid in the synthesis of new organic materials.

shooting for MACH 33

DEREK G. MOORE, *Fluid Dynamics Facilities Laboratory*, ARL

Plans formulated in 1958 to provide the ARL with facilities for conducting research in fluid mechanics included a hypersonic wind-tunnel complex capable of simulating certain flight parameters in the Mach-number range of 8 to 33. This goal was to be achieved in three phases, utilizing a common air-supply system and funded incrementally in step with the state-of-the-arts of materials and aerodynamics. The first two phases have reached operational status: Phase 1, a 20-inch-diameter tunnel heated by electrical resistance elements operating up to M 16; Phase 2, a 30-inch-diameter tunnel heated by a zirconia pebble bed operating between M 16 and M 22. Operational status for the third phase is at least five years away; and although several attractive approaches are being seriously studied, no decision can yet be made as to what form the higher-Mach-number facility will take.

Use of the conventional type of hypersonic wind tunnel employing the isentropic expansion of air in a nozzle is limited by the phenomenon of air condensation in the nozzle, which may occur when the decreasing pressure and temperature of the expanding flow reach or exceed the air saturation point. Condensation may be avoided by heating the air to stagnation temperatures sufficiently high so that the static temperatures throughout the expansion are greater than the air saturation temperature. At high Mach numbers, this approach becomes impractical due to the prohibitively high stagnation temperatures required. Even at Mach 18 a theoretical stagnation temperature of 4000°R is required, and it is only because an apparent supersaturation occurs that it is

possible to operate the ARL 30-inch tunnel at the higher Mach numbers with stagnation temperatures on the order of 3000°R. Until such time as it may be possible to heat, contain, valve and expand high-pressure air at higher temperatures, other methods of conducting hypersonic experiments must be searched for. With this in mind, a free-flight testing technique, consistent with the testing technology state-of-the-art, is being studied with a view to providing an interim high-Mach-number testing capability quickly and economically as an adjunct to Phase 2 prior to the construction of a facility for Phase 3. Details are described in a technical report, ARL 63-135, recently released.

The free-flight testing technique consists of firing a sabotted model counterflow to a high-Mach-number air stream, thereby increasing the Mach number of the model relative to the flow. The model would be fired upstream through the test section of the ARL 30-inch hypersonic wind tunnel from a two-stage, light-gas gun located in the diffuser section of the tunnel. This type of gun has been developed to the point where a model weighing ¼ lb can be launched at velocities of 10,000 fps without exceeding present-day operating limits. With the tunnel operating at Mach 18, this would give the facility a test Mach-number capability of 18 to 45. The stagnation temperatures experienced in the nose region of a blunt model would cover the range of approximately 3000°R to 10,000°R, a significant increase unattainable by conventional means at the present time.

The concept of firing models against an established air flow is not new, successful application to a supersonic tunnel having already been made by the NASA Ames Laboratory. However, application to a hypersonic tunnel greatly magnifies some of the inherent problems of the technique.

With respect to the feasibility of the technique, the crucial problem is the obvious need to catch the model after it has passed through the test section. For any given nozzle-exit diameter, a hypersonic nozzle has a smaller throat than a supersonic nozzle having the same exit diameter. The result is that the Ames technique of catching the model after it has passed through the throat can no longer be employed at high Mach numbers. The Mach-18 nozzle of the 30-inch tunnel has a throat diameter of only.195 in., which means that any useful-sized model would either have to be caught in the nozzle downstream of the throat or be allowed to pass through an outlet in the nozzle wall into an external receiving chamber. It should be remembered that the model-catching system must not disturb the flow delivered in the test section. A possible solution to the problem might be to fire the model off-center, but parallel, to the nozzle axis, allowing it to pass through a frangible diaphragm located in the nozzle wall. A guarantee of clean model penetration without damage to the expensive nozzle would have to be proven by full-scale mock-up tests.

Apart from the feasibility standpoint, there is the question of how much useful information could be obtained by performing such tests.

Due to the limited length of the test section (i.e., the length of the free jet between the nozzle exit and diffuser inlet) and the high model velocities, small response times are required of instrumentation. Stability measurements are almost certainly out of the question due to the low air density and restricted testing length; but some stagnation point measurements on blunt bodies might be possible. The fact that ARL has been able to obtain schlieren photographs at Mach 16 is very encouraging, since this would indicate that schlieren pictures could be taken with a high-speed framing camera to provide information on shock formations at the very high Mach numbers.

In conclusion, initial studies suggest that free-flight testing in the ARL 30-inch hypersonic wind tunnel is ostensibly feasible and attractive for achieving high Mach numbers and for duplicating high stagnation temperatures in the nose region of projectiles. Although the technique would alleviate the difficult problems of producing and containing high-temperature air, the problem of collecting reliable data becomes severe. A closer study of this problem is necessary to further evaluate the limited potential of the technique before any experimental research on a model-catching system is performed.

dedication of the ARECIBO radio telescope

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Microwave Physics Laboratory, AFCRL

Dedication ceremonies were held on 1 November 1963 for the world's most powerful radio-radar telescope at Arecibo, Puerto Rico. This telescope represents the culmination of a four-year, nine-million-dollar effort by Cornell University, the Advanced Research Projects Agency, the Air Force Cambridge Research Laboratories, and the Army Corps of Engineers.

The Arecibo telescope, with a reflecting dish measuring some 1000 feet across, was built into a natural depression in an isolated area of Puerto Rico. The special feed mechanism, which grew out of research conducted at AFCRL on the correction of spherical aberrations, will permit the radar to scan over a 40-degree cone. Scanning is accomplished by moving the feed mechanism with respect to the dish. The Arecibo radio telescope will be used for research related to military programs in communications, ballistic-missile detection, and tracking.

The total dish surface covers about 18.5 acres. The concept for the Arecibo dish was originated by Prof. William E. Gordon of Cornell University, who has been appointed director of the facility. The novel dish configuration, consisting of a partial sphere, was based on research by scientists at the Air Force Cambridge Research Laboratories. In such a configuration, unlike the more conventional paraboloid reflectors, collected energy is not focused at a single point. However, the energy does fall along a single line. By gathering the energy along this line, it is possible to achieve, in effect, a central focus. The phased-line source feed, consisting of a 96-foot-long wave guide which is used to focus the received energy and to properly distribute radiated energy over the spherical reflector, evolved from research at AFCRL in the early 1950's.

Following are the basic parameters of the Arecibo antenna: frequency: 430 Mcps; average power: 150 Kw; peak power: 2-1/2 Mgw; PRF: up to 1000 cycles; antenna beamwidth: 1/6 degree; aperture: 1000-foot diameter; radius of curvature: 870 feet; and height of feed above reflector: 435 feet.

CHEMICAL abstractions

ALFRED WEISSLER, *Directorate of Chemical Sciences*, AFOSR

The use of advanced mathematical theories to explain the properties of matter provides a valuable supplement to traditional chemical approaches. Interesting work in this field has been accomplished by Dr. Bernard D. Coleman at the Mellon Institute, under an AFOSR contract.

An example is his mathematical treatment of the mechanical behavior of fluids, including such complications as shear-dependent viscosity and gradual stress relaxation. His general theory of "simple fluids with fading memory," developed in collaboration with Dr. Walter Noll, is based on mathematical definitions of the concepts.

Translated into ordinary language, a simple fluid is one which has no intrinsic preference for a particular configuration out of a class of configurations of equal volume; that is, it takes the shape of the confining vessel. Similarly, the principle of fading memory states that deformations which occurred in the distant past should have less effect on the present value of the stress than deformations which occurred in the recent past.

The theory obtained by mathematical reasoning from these concepts was found to be broadly applicable to fluids. Even complex systems such as molten polymers or polymers in solution were found by the theory to

show ideal or "Newtonian" behavior in the limit of very slow flow, and linear viscoelastic behavior in the limit of infinitesimal deformations.

Among other topics treated by Dr. Coleman were the thermostatics of continuous media, helical flow of general fluids, and normal stresses in second-order viscoelasticity.

One of Dr. Coleman's collaborators on the AFOSR contract, Dr. A. Silberberg, worked out an improved theory for the adsorption of flexible macromolecules at a plane surface. He started from the known facts about the shape of the adsorbed polymer molecule, and the dependence of the adsorption isotherm on the concentration, temperature, pressure, molecular weight, and surface tension. Next he introduced a model in which the adsorbed polymer molecules were attached to the interface by stretches of segments in the surface, alternating with loops hanging away from it. These loops were considered as a polymer-rich thin new bulk phase, adjoining the surface. Figure 1 shows these adsorption loops, and some of the restrictions on them treated in the theory.

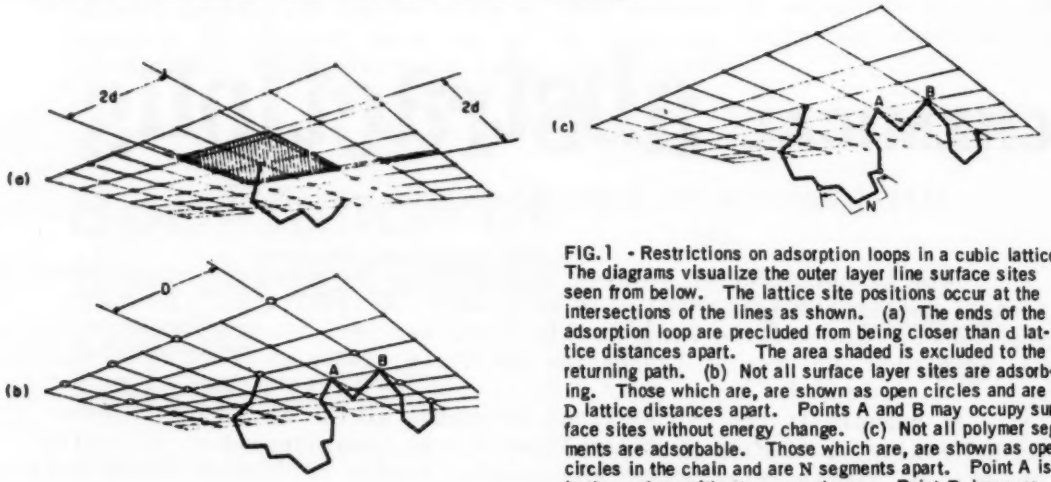

FIG. 1 - Restrictions on adsorption loops in a cubic lattice. The diagrams visualize the outer layer line surface sites seen from below. The lattice site positions occur at the intersections of the lines as shown. (a) The ends of the adsorption loop are precluded from being closer than d lattice distances apart. The area shaded is excluded to the returning path. (b) Not all surface layer sites are adsorbing. Those which are, are shown as open circles and are D lattice distances apart. Points A and B may occupy surface sites without energy change. (c) Not all polymer segments are adsorbable. Those which are, are shown as open circles in the chain and are N segments apart. Point A is in the surface without energy change. Point B, however, represents an adsorption.

The adsorption behavior predicted by the theory (with the help of a new method for getting the entropy of mixing or "disorderedness" of polymer molecules with low molecular weight solvent) was found to fit the observed facts very well. For example, the amount of adsorption was correctly found to reach a plateau value which is constant over a wide range of concentration, but which is increased for higher molecular weights. Also explained were the observed slow approach to equilibrium and the inability to wash off adsorbed polymer films.

Research such as this provides the Air Force with a powerful technique for predicting and modifying the performance of materials such as plastics, lubricants, and rubber.

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